Elevator Group Control Systems for Avoiding Cage Lump States

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Elevator Group Control Systems for Avoiding Cage Lump States

Naoyuki Tamaru *

Abstract

This paper describes three control methods for an elevator group established in high story buildings in order to decrease the waiting time from an elevator cage call to a cage arrival. It is stated that it is important to reduce a lump state for multi cages, i.e. a jam state of cages, in order to decrease the waiting time. We study three simple methods, that is to say, a minimum method, a direction priority method and a speed method. In the direction priority method the cage moves so as to trace almost the ideal trajectory like the Ferris wheel. We construct a simulation program using the Visual Basic, generate random story numbers for call stories and target stories of elevators, and collect the waiting time and the lump number using this simulator, and analyze advantages and disadvantages for three methods. The generated rate for the first floor is changing from 10 % to 40 % because the first floor is mainly uses for passengers.

After we evaluate quantitatively the simulation results using random numbers, the minimum method is recommended among the three methods from the viewpoint of the waiting time. Moreover, there is a week correlation between the waiting time and the lump number only in case of the minimum method.

Key Words : elevator, control, group control, cage lump state, waiting time

1. Introduction

Recently many high story buildings have been constructed in large cities of Japan. In these buildings multi-cage elevators are established and unavoidable. The higher the buildings are, the longer the waiting time in front of the elevator door for riding into an elevator cage is, in general. Passengers who request to move another story in an elevator hall cannot wait for longer seconds. Then it is necessary for the elevators to become higher performance. It is important to reduce the waiting time.

It is very important to allocate a proper cage for the request or the call, because the elevator performance greatly changes. There are many

* *Faculty of Social Information Studies, Otsuma Women's University*

studies concerning about the cage allocation method, such as GA(Genetic Algorithm)[(1),(2)], Neural Networks[(3)], Fuzzy[(4),(5),(6)], AI (Artificial Intelligence)[(7)], a transport schedule method[(8),(9),(10)], a search algorithm A[(11)], and so on.

The paper (1) states about an elevator group-supervisory control system using the genetic algorithm. Here each floor situation is considered such as the waiting time and the passenger density in cages.

The paper (2) states about an elevator parameter tuning method using the improved genetic algorithm in order to follow environment changes and to give robustness.

The paper (3) states about a detection system of typical elevator traffic patterns with neural networks. This advantage is easy to apply any buildings.

The paper (4) states about a supervisory control system which improves plural control objects, such as the waiting time and the riding time.

The paper (5) states about a group- supervisory control system which uses the expert knowledge in the fuzzy rule-base.

The paper (6) states about a review of group elevator control systems and adaptable examples for AI technologies.

The paper (8) states about a schedule system for the elevator group control.

The paper (9) states about an elevator supervisory control algorithm which is based on simulation of the predicted transport schedule of each cages.

The paper (10) is proposed a novel technology that each elevator is controlled so as to follow the moving trajectory along the ideal trajectory with equal cage distances each other.

The paper (11) describes about an elevator supervisory group control system which uses a search algorithm A.

In these papers there are not detail analyze of the results, and they does not evaluate quantitatively for random story numbers. We select three simple methods, a conventional minimum method, a direction priority method, and a speed method. In the second method of the direction priority method, we change the ideal trajectory method(10) to the simpler method. Then we evaluate them concerning about advantages and disadvantages, using a programed simulator against random story numbers.

In Section 2, we introduce a purpose of elevators, control conditions of elevators, and so on. In Section 3, we describe about the three control methods and the control programs. The experimental results by the computer simulation are shown also in Section 3. Finally, the paper is briefly summarized in Section 4.

2. Elevator Functions

2.1 Purposes of Elevator

The purposes of elevators in a building are for passengers to transfer speedy and safely from a called story where a passenger requests to move, to the other target story. The elevator group control processes step by step as below.

(i) A passenger pushes a direction button of upward or downward in an elevator hall, i.e. a cage call.

(ii) An elevator control system allocates the proper cage among the elevator group, and orders it to send to the called story.

(iii) The passenger enters into the cage when the allocated cage reaches to the called story, and pushes the target story button in the cage.

(iv) The control system transfers the passenger to the target story.

2.2 Initial Conditions

As initial conditions there are four terms in order to reduce the complexity of the calculations. The first is that there is no called cages, and no change of the target story for cages while cages are moving, i.e. throughout the one service process. The second is that any other services do not start before the present service finishes, i.e. simultaneously multi cages do not move. The third is that the multi passengers are allowed in one cage, but the same process is kept during this service, i.e. any persons do not get off or get on the cage on the way to the target story or the called story. The fourth is that there is the 10th floor building of an university, there are several class rooms below 5th floor, and there are teacher's office rooms more than or equal 5th floor.

2.3 Control Valuation

There are the waiting time and the number of the lump state concerning about the control quality. The waiting time is defined as the interval from the push time for the direction button to the cage arrival time to the requested or the called story, that is to say the time to send a cage to pick up a passenger. If the moving speed of the elevator is constant, the waiting time is proportional to the difference moving stories to send a cage in order to pick up a passenger. Therefore, the waiting time is meant as the waiting story number, after here. If the waiting time is more than 30 seconds, persons more than 60 % start to get irritated[12].

The lump state is defined as all cages concentrate within 3 stories. In general while the cage lump state occurs, the waiting time increases. Especially at a start of lunch time many cages are concentrated to the first floor in order to go out to the other building for the cafeteria.

3. Elevator Control Methods

3.1 Variations

We have studied three control methods for the multi elevator system. The first is a minimum moving story method that the cage travel distance becomes minimum story number in order to access to the story for the requested parson. That is to say, the waiting time for the cage is a minimum.

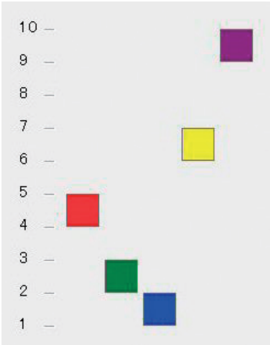


Fig. 1 An example of a cage placement for group elevator systems

For example, if the requested call occurs at the 8th story in the Figure 1, the fifth purple cage from the left side (i.e. stopping at the 10th floor) is accessed to the story. The bottom line of each square cage represents the story number, shown in the left vertical axis.

The second is a cage moving direction priority method that the cage direction for the former direction coincides with the next direction to be moved in the same cage when the cage accesses to the requested story. Moreover, if there are plural proposed cages for the rule, the minimum story method is adopted for these cages. In this method the ideal moving trajectory is the same as the trajectory of a Ferris wheel that the cage distances are same as each other. But the control that each cage distance becomes almost equal, can not be achieved. Each cage keeps the former moving direction. When the cage reaches to the first floor from the upper story, the cage direction changes to upward from downward. In similar, when the cage reaches to the 9th story or the 10th story, the cage direction changes to downward from upward. If there is no cage adopting this rule, the minimum story method is used.

For example, if the downward requested call occurs at the 4th story in the Figure 1. the fifth purple cage from the left side is accessed to the story. In this case it is supposed that the former direction of the first, the second, the third, and the fourth cage is upward, and that of the fifth cage is downward.

The third is a speed cage moving method that the cages with rapid moving and regular speed moving are mixed, the former is that the stoppable stories are limited, the latter is that every stories are capable to be accessed.

For example, if the called cage occurs at the 6th story with the target story of 4 in Figure 1, the first red cage from the left side. In this case it is supposed that the fourth and fifth cage is adopted as the speed method where the second, the third and the fourth story is not capable to access.

3.2 Programing

We use Microsoft Visual Basic 2017 as the cage moving calculations. Figure 2.(a) shows the computer image just after the program starts. There are 5 square cages with 5 colors at the first floor. At the top left of the image there are two textboxes, the call story number in the first box, shown by “CALL”, and the target story number in the second box, shown by “TARG”. There are random numbers of the first 6 pairs in the boxes. The number of 8 and 5 is the first pair, and that of 7 and 3 is the second pair. At the right bottom there are two buttons, as “START” and “END”.

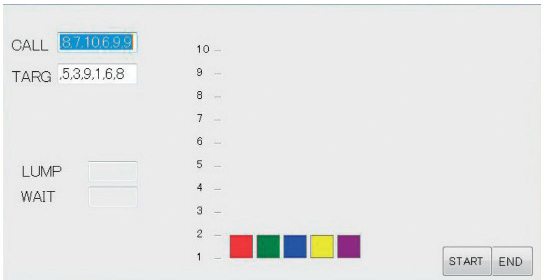
Figure 2.(b) shows the computer image just before the program ends. At the left side of the image there are two textboxes, the total lump number shown by “LUMP” and the total waiting time shown by “WAIT”, respectively.

The concerned building with group elevators is 10 stories. Then random numbers from one to ten are generated in the program. A pair is consisted with a call story number and a target one. The former is the story where a passenger requests or calls a cage in order to move a target story. The latter is the target story number button that he/she pushes in the cage.

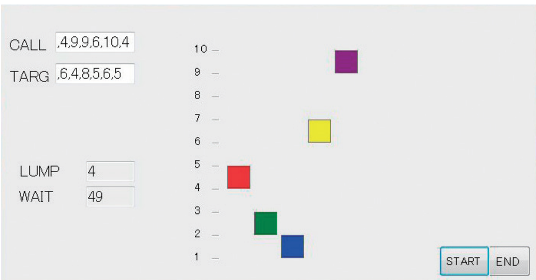
In one pair the numbers are not the same, and the number ranged from 2 to 10 is generated so as to be the same generated rate. The one story is special because of mainly used story number for the entrance. The generated rate for one story is changed from 10 % to 40 %. At the rate of 10 % the rate of every number from one to ten is equal to 10 % (=100 % / 10).

As the initial condition for the calculation program every cage stops at the first floor. The generated numbers change at each run of the program, and they are stored in the computer memories by the array format, just after the program runs in advance.

In the program a pair of random numbers is read out from the computer memory, and it allocates one optimum cage to send to the called story according



(a) An image at the program beginning



(b) An image at the program ending

Fig. 2 An Example of the computer image for the elevator simulator

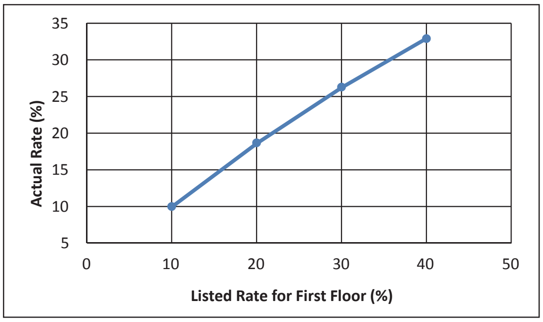


Fig. 3 A relationship between the listed rate for the first floor and the actual rate

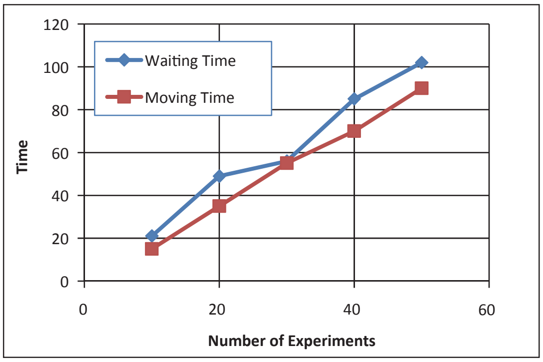


Fig. 4 A relationship between the number of experiments and the times

to the pair number in order. Therefore, while one process is running, it does not interrupt on the way. Then the moving cage does not stop at another story, ether does not change the target story. The running time of the program is about 35 seconds for the 20 pairs of the random numbers with every 50 micro-second wait par a pair number. At the end of the program the lump number and the waiting time is displayed in the image.

Figure 3. shows a relationship between a listed rate for the first floor and an actual generated rate. The former is used in graphs and texts with simplicity. This difference of the rate is caused from removing the same random numbers among a pair. For example from the figure the listed rate of 30 % becomes about 26.4 % actually.

Figure 4. shows a relationship between the

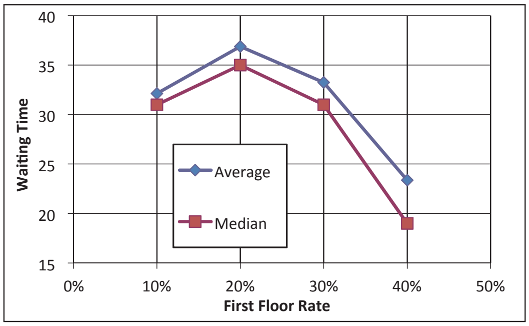


Fig. 5 A relationship between the average data and the median data for the experiments

number of experiments, i.e. the number of a pair, and the time in the case of the speed method with 2 speed cages against the total 5 cages on the first floor rate of 30 %. In the figure the blue line with diamond plots shows the total of the waiting time, that is to say, the waiting time from the press time of the cage call button to the passenger enter time. The red line with square plots shows the travelling time from the passenger enter time to the target story reaching time. The time for the vertical axis is the median value among 8 experiments, defined by the story number. In each experiment there are from 10 pairs to 50 pairs of random numbers. When the cage moving speed keeps constant, the total waiting time is proportional to the total moving story.

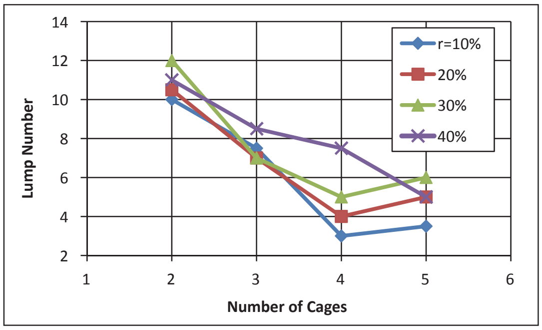
From the figure the waiting time and the moving time increases according to the number of experiments without perturbation, naturally.

3.3 Comparison of Three Methods

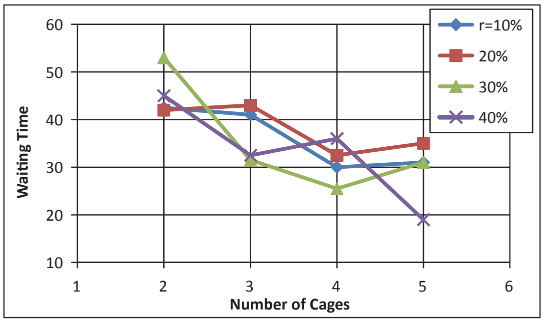
3.3.1 Minimum Method

Figure 5. shows a relationship between the first floor rate and the waiting time in the case of the 5 cages. From this figure the median values are smaller than the average values almost in every case. Therefore, the median values are used in every graph.

Figure 6. shows the waiting time and the lump



(a) The waiting time VS. the number of cages



(b) The lump number VS. the number of cages

Fig. 6 The experimental results for the minimum method

number against the number of cages for the minimum method in the first floor rate of 10 % to 40 %. The vertical axis represents the waiting time in Fig. 6.(a), the lump number in Fig. 6.(b), respectively.

Though from Fig. 6.(a) the waiting time for the rate of 40 % becomes a large perturbation, it is supposed that similar to the other rates the waiting time decreases gradually according to the number of cages by the increasing trials. In case of the 4 cages the waiting time is the smallest in the rate of 10, 20 and 30 %, i.e. except 40 % rate. The lump number of the 4 cages is also smallest in almost every rate.

From Fig. 6.(b) the lump number for the 4 cages becomes the smallest in case of the rate of 10 % to 40 % in order.

From Fig. 6. shows that in case of the cage number of 5 the waiting time and the lump number

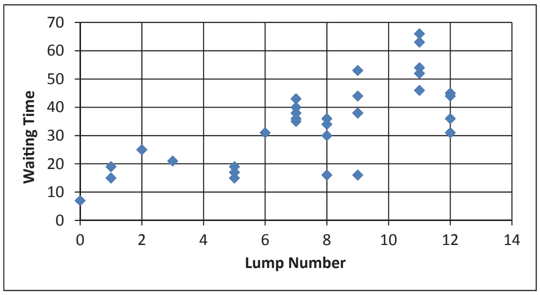


Fig. 7 A relationship between the waiting time and the lump number for the minimum method

becomes large, because the cages do not scatter among first to tenth story.

Figure 7. shows a relationship between the lump number and the waiting time for the minimum method in case of 2 to 5 cages, the first floor rate of 40 %. The plot number is 32 (= 8 × 4). Here, number 8 is the number of experiments with the same condition, and number 4 is the kinds of cage number, i.e. 2, 3, 4 and 5 cages.

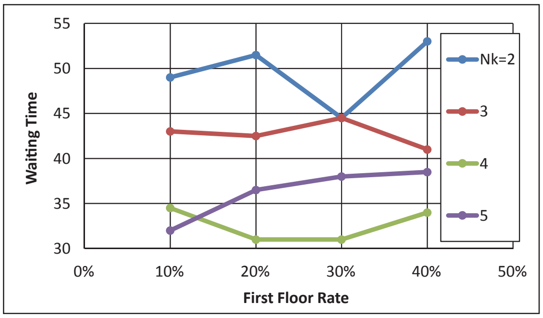
From the figure a little strong correlation is exists among two parameters. The correlation index is 0.731. The same as this it is 0.664 in case of the first floor rate of 30 %. It is a week correlation.

3.3.2 Direction Priority Method

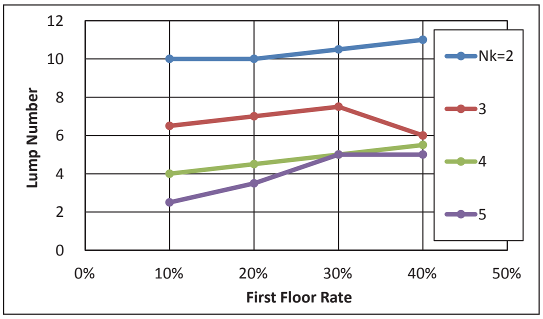
Figure 8. shows the waiting time and the lump number against the first floor rate. The vertical axis represents the waiting time in Fig. 8.(a), the lump number in Fig. 8.(b), respectively.

From these figures the waiting time becomes the smallest in case of the 4 cages at the rate of 20, 30 and 40 %, the lump number does the smallest for the 5 cages at the every rate.

As the correlation index is 0.586 in case of the direction priority method, the cage number of 5, there is a week correlation. The same as this it is 0.161 in case of the cage number of 4. A correlation does not exist almost.



(a) The waiting time VS. the first floor rate



(b) The lump number VS. the first floor rate

Fig. 8 The experimental results for the direction priority method

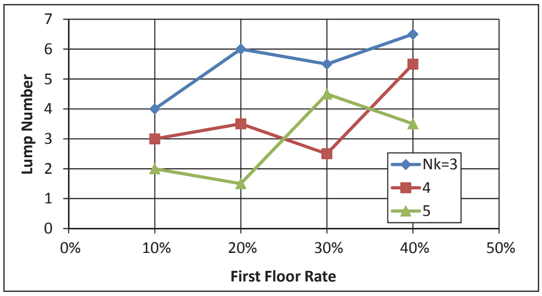
3.3.3 Speed method

Figure 9. shows the waiting time and the lump number against the first floor rate in case of two cages with the speed mode. The vertical axis represents the waiting time in Fig. 9.(a), the lump number in Fig. 9.(b), respectively.

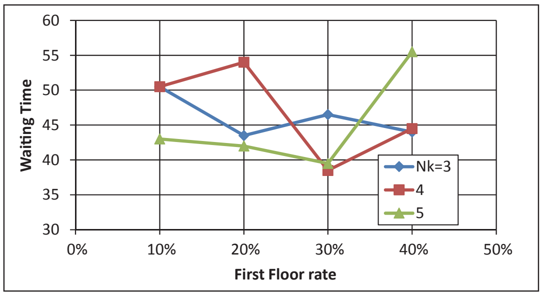
From Fig. 9.(a) in case of 5 cages the waiting time becomes the smallest at the rate of 10, 20 and 30 % except 40 %. From Fig. 9.(b) in case of 5 cages the lump number becomes the smallest at the rate of 10, 20 and 40 % except 30 %.

Figure 10. shows the waiting time and the lump number against the first floor rate in case of the total five cages. The parameter of these figures is the number of the speed mode among five cages. The vertical axis represents the waiting time in Fig. 10.(a), the lump number in Fig. 10.(b), respectively.

From Fig. 10.(a) when the speed mode cage is

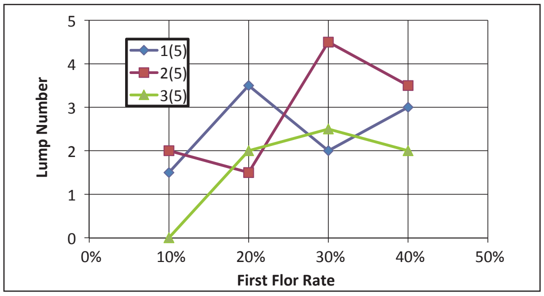


(a) The waiting time VS. the first floor rate

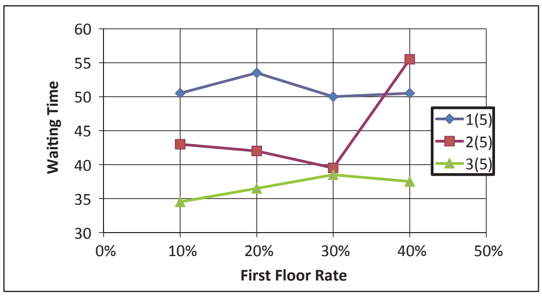


(b) The lump number VS. the first floor rate

Fig. 9 The experimental results for the speed method



(a) The waiting time VS. the first floor rate



(b) The lump number VS. the first floor rate

Fig. 10 The experimental results for the speed method with the constant total cages of five three, the waiting time becomes the smallest at the rate of 10 to 40 %. From Fig. 10(b) the lump number becomes almost the smallest when the speed mode cage is three.

When the speed mode cages are one, two, three among the total cage number of 5, the correlation index is 0.517, 0.333 and 0.269, respectively. Therefore the correlation does not almost exist in case of the speed method because the speed mode cages do not stop at the predetermined stories and gather each other apart from the regular cages.

3.3.4 Summary of Results

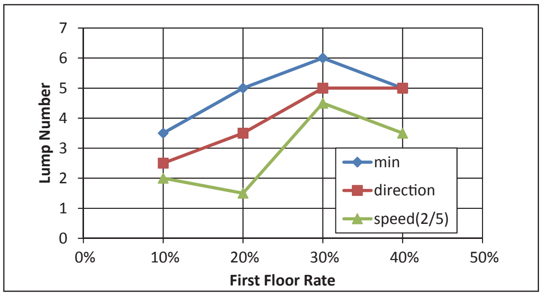
Figure 11. shows the waiting time and the lump number against the first floor rate in case of the total five cages. The parameter of these figures is three methods. The vertical axis represents the waiting time in Fig. 11.(a), the lump number in Fig. 11.(b), respectively. About explaratory charts in these figures “2/5” indicates 2 cages for the speed mode among 5 cages.

From Fig. 11.(a) the waiting time for the minimum method becomes the smallest among three methods. The direction priority method is the second. From Fig. 11.(b) the speed method becomes the smallest. The direction priority method is also the second at the rate of 10 % to 40 %.

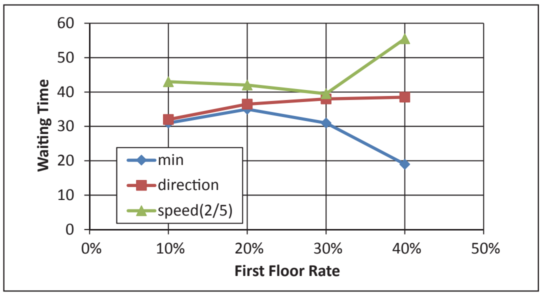
Therefore the direction priority method is recommended because the waiting time and the lump number is the middle rank among the three methods.

Figure 12. shows the waiting time and the lump number against the first floor rate in case of the total four cages. The vertical axis represents the waiting time in Fig. 12.(a), the lump number in Fig. 12.(b), respectively.

From Fig. 12.(a) the waiting time is the smaller with almost an equal waiting time between the minimum method and the direction priority method for the first floor rate of 10 % to 40 %. The waiting time for the speed method with two speed cages is

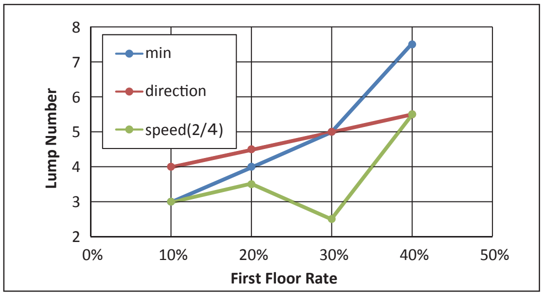


(a) The waiting time VS. the first floor rate

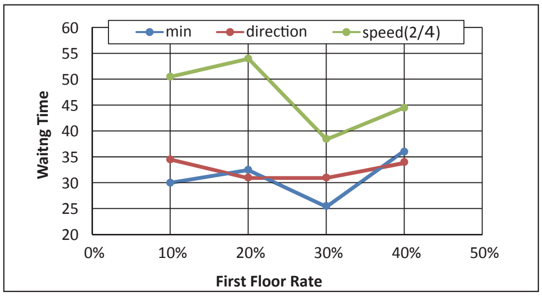


(b) The lump number VS. the first floor rate

Fig. 11 The summary experimental results for the three methods with the constant total cages of five

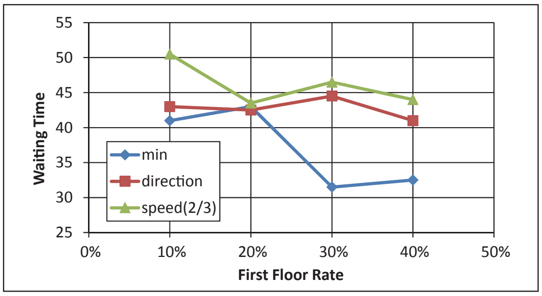


(a) The waiting time VS. the first floor rate

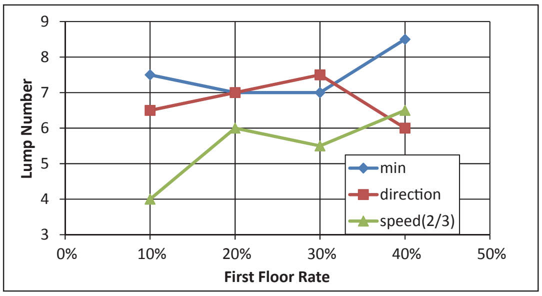


(b) The lump number VS. the first floor rate

Fig. 12 The summary experimental results for the three methods with the constant total cages of four



(a) The waiting time VS. the first floor rate



(b) The lump number VS. the first floor rate

Fig. 13 The summary experimental results for the three methods with the constant total cages of three

larger than the other methods.

From Fig. 12.(b) the lump number for the speed method becomes the smallest in case of the rate range of 10 % to 40 %.

Figure 13. shows the waiting time and the lump number against the first floor rate in case of the total three cages. The vertical axis represents the waiting time in Fig. 13.(a), the lump number in Fig. 13.(b), respectively.

From Fig. 13.(a) the waiting time for the minimum method is the smallest especially for the first floor rate of 30 % to 40 %. The waiting time for the other methods is almost the same.

From Fig. 13.(b) the lump number for the minimum method becomes the smallest in case of the rate range of 10 % to 30 %.

There is not really a correlation between the waiting time and the lump number except for the week correlation of the minimum method. Therefore the lump number is the necessary condition for the waiting time, but is not the sufficient condition.

Table 1 The best selection among the three methods concerning with the waiting time

Cages	10 ～ 20 %	30 ～ 40 %
3	M, D	M
4	M, D	M, D
5	M, D	M

Table 1 shows the effective method concerning about the waiting time when the number of cages and the first floor rate changes. In the table "M" refers the minimum method, and "D" does the direction priority method. When there are two methods in a cell, these two methods are almost equivalent. From the table the minimum method is the best selection in case of the rate range of 10 % to 40%, and the cage number of 2 to 4.

There is an elevator control system having a cage door that is open during a predefined time after a passenger gets out of the cage at the target floor. In this case, it is very effecive for reducing the waiting time when the cage at once moves to the called story with the door closed.

4 Conclusion

It is very important to allocate a proper cage for the request or the call in multi-elevator systems, because the elevator performance greatly changes. This paper presents a simple group elevator control system, especially cage allocation methods. We compared three simple methods by the construction of a simple simulator that generates random numbers as call stories and target stories.

From the simulation results the minimum method is the best selection in case of the first floor rate range of 10 % to 40%, and the cage number of 2 to 4 at the viewpoint about the waiting time. Moreover, there is a week correlation between the waiting time and the lump number only in case of the minimum method.

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